Dual Carrier Preparations for Viking

D. A. Bathker
Communications Elements Research Section
D. W. Brown
R. F. Systems Development Section

While simultaneous transmission of two S-band carriers from a single Deep Space Station is no longer a committed operating mode for Viking Project support, the program of investigation and abatement of noise bursts and intermodulation interference has continued through the first three calendar quarters of 1973. At DSS 14, internal waveguide and external antenna work yielded major reductions in both types of interference. Supporting investigations were also conducted at JPL and at DSS 13 during this period. Conclusions and recommendations for future work are presented.

I. Introduction

The continuing program of investigation and abatement of interference arising from single- and dual carrier transmission from a Deep Space Station shifted emphasis to DSS 14 early in 1973. The extensive work at DSS 13 during 1972 (Refs. 1 and 2) was continued in the first half of 1973 in order to obtain long-term data and to perform specific experiments in support of the 64-m antenna effort. This work has been reported in detail by Petty and Jackson (Refs. 3 and 4). This article will emphasize results at DSS 14 and, with the aid of an extensive reference list, will serve as a final report for the 1972–1973 program.

On the whole, the effort at DSS 13 served the intended purpose of confirming prior hypotheses, identifying sources of interference, developing remedial procedures, and establishing improved methods of instrumentation. Although significant reduction of internal sources and of selected portions of the external system at DSS 13 was achieved, little was to be gained by further work on the DSS 13 unique antenna structure.

II. Supporting Investigations

Analysis and modeling of various aspects of the dual-carrier problem have continued, with the objective of backing the empirical field work with sound theory (Refs. 5–9). Of particular interest is the work by Higa and others (Ref. 7), including laboratory generation of broadband noise and intermodulation products (IMPs) in the receive band by means of RF-illuminated junctions of oxidized aluminum. More recently, a quantum physics model has been applied (Ref. 9), largely confirming past hypotheses of tunneling effects in the myriad metal–oxide–metal junctions in the external antenna.

More closely allied to the field activities was the evaluation by Kent (Ref. 10) of the degradation of telemetry and doppler data in the interference environment. With the aid of a controllable IMP generator (Ref. 11), a range of performance was obtained, yielding the conclusion that, in general, for carrier loop margins near 20 dB (typical of Viking orbital operations), the presence of detectable receive band IMPs will produce detectable data degradation.

In yet a different context—Viking orbiter uplink and downlink spectrum analysis—Koerner has included the IMPs along with modulation sidebands and the multiple carriers in determining mutual interference in communication links (Refs. 12 and 13).

III. Summary of DSS 14 Activity

As indicated at the close of the last major dual-carrier activity report (Ref. 2), a return to DSS 14 was authorized at the beginning of 1973. The initial scope was set at the accomplishment of whatever modifications could be made during the then scheduled station down time in February and March. In addition to a work plan for this period, tests were designed and scheduled for "before and after" interference performance during January and April–May. As of the end of May, the ten-fold improvement achieved (more on this in the next section) was sufficient to uncover a level and type (spectral quality) of interference which pointed strongly to the highly illuminated feed cones with their newly installed S/X-band hardware. This latter equipment was added during the aforementioned down time and consists of an ellipsoidal reflector atop the S-Band Megawatt Transmit (SMT) cone and a dichroic plate over the Multiple-frequency X- and K-Band (MXK) cone (Ref. 14). It had been anticipated that these items with their piece-part construction (rivets, etc.) and hydraulic retraction mechanisms would prove to be troublesome in the interference sense.

Because of the then approaching Mariner Venus/Mercury 1973 (MVM'73) preparations and Pioneer 10 configuration freeze, it was considered inadvisable to undertake any modifications to this critical equipment for the purposes of interference abatement. However, in order to capitalize on the gains already achieved, a plan was devised to remove intact the SMT and MXK cones with the primary intent of evaluating the basic antenna with only the relatively simple (externally speaking) Polarization Diversity S-Band (PDS) cone in place. Evaluation in this configuration not only indicated further reduction in interference level but uncovered yet new clues pointing primarily to the quadripod apex and legs. Here again, a work plan was developed to complement an already scheduled survey and reconditioning of the main reflector. In order to maintain test configurations as orderly as possible, the re-installation of the cones was delayed somewhat, with the MXK going up near the first of August and the SMT about one month later.

More test time during and after this effort would have allowed more satisfying cause-and-effect conclusions to be drawn, but thanks to the extraordinary efforts of DSN scheduling, station personnel, and key people from Sections 332, 333 and 731, additional improvements of 100-fold and more (30 dB since January) were obtained with sufficient control to firmly establish the re-installed cones and related equipment as the limiting interference sources.

Table 1 attempts to summarize these DSS 14 activities for the purpose of establishing a time line for the discussion to follow, which will present the performance achieved at each step. The important detail behind the modification summary given above will be reported separately[1] (see also Ref. 15).

IV. Performance Results At DSS 14

Considering the completion times of Table 1 as the abscissa and the IMP mean averaged over the available test periods as the ordinate, we obtain Fig. 1. As noted, all performance data are for the standard test conditions of dual 40-kW carriers at approximately 6-MHz spacing ($N = 31$)[2].

The "pre-1973" data point is typical of observations in 1972 and perhaps earlier. The 2- to 3-dB improvement indicated in the first interval is illustrative of the concept that for many discrete interference sources, eradication of less than a majority (assuming equal intensity for each) will result in less than 3-dB reduction in overall level.[3] Keeping Table 1 in mind, we see a 10-dB reduction

[1]To be published.

[2]N is the index of the Nth spectral line above the upper carrier (Ref. 2).

[3]See first part of Ref. 15 for "pre-1973" modifications.

achieved in the next interval, which represents the addition of the S/X feed cones, down time modifications, and replacement of such internal waveguide items as switches and diplexer. While some data were taken in the SMT diplex mode as well as with the PDS cone, which proved helpful on a detailed diagnostic level, in general, the interference performance was essentially the same with either cone active (Ref. 16). For the purposes of this article, it is sufficient to consider all data as taken in the PDS mode.

As of late May, the IMP mean had not only been reduced to typically −150 dBm (from −140 dBm in January), it had also taken on a more stable character (i.e., less variance). Similarly, the single- and dual-carrier noise burst (NB) performance had made proportional improvements (Fig. 2). As noted in the preceding section, the SMT and MXK feedcones were then removed, with an immediate 6- to 10-dB improvement. By late July, minor modifications, primarily near the surface of the main reflector, had yielded exceptionally interference-free performance: IMP means of −170 dBm *and less* and NB peaks in the 3-K range, except upon mechanical agitation of the quadripod apex/subreflector assemblies. As indicated in Fig. 1, this effect had first been uncovered during the prior test period, and was a primary consideration in the formulation of the August work plan (see Table 1).

Station commitments forced the re-installation of the MXK cone during the August modifications, with a result that precluded the possibility of observing a probably stable interference level of −170 dBm or less. Nonetheless, evidence in mid-August strongly indicates that the intermittence had been subdued, even though a new stable IMP level of −160 dBm resulted in this configuration. By late August, with essentially all modifications complete, the IMP level had apparently risen to −155 dBm. As Table 1 indicates, the main reflector had been stripped of tape and retaped during this month, but with dry weather in this period, it is believed that tape was not a factor in the August performance data.

Two apparently unrelated circumstances are of interest for this period. First, as noted in Table 1, the 400-kW klystron failed at about the time the feed cones were removed, and because spares had been temporarily consumed by other high-power transmitter problems, it was necessary to adopt the 100-kW configuration as planned for DSS 43 and 63. In order to maintain continuity of test condition, dual 40-kW operation with the 100-kW klystron was attempted and just achieved with close monitoring of operating conditions (i.e., RF drive, beam voltage, etc.). While this mode considerably exceeded the 10% per carrier nominal operating power (Ref. 2), with resulting increased level of low-order (uplink) intermodulation sidebands in the transmitter output, special tests were conducted which indicated that the *receive band* IMPs were probably typically generated and, if anything, this configuration would yield data on the conservative side. This transmitter configuration prevailed throughout the balance of the year.

Secondly, beginning at the mid-August tests and continuing thereafter, the prevailing IMP levels of −160, −155, and finally −150 dBm in September became consistently more sensitive to carrier operating level. As seen in Fig. 3, a 3-dB reduction (to dual 20 kW) produced less receive band IMPs in ratios approaching 30 dB (−150 to −180 dBm). All prior experience—early 1973 as well as both DSS 13 and DSS 14 in 1972—suggested a cube law effect (approximately 9 dB per 3 dB) (see Fig. 2 of Ref. 2). The clear implications here are that the July and August effort not only subdued the dual 40-kW intermittent but achieved a lasting reduction of the cube law mechanism by as much as 20 to 30 dB (referred to the 20-kW level), and that the implied interference sources associated with cone re-installation are of intrinsically different type from those generally observed prior to that time. This conclusion reinforces earlier hypotheses concerned with loose as opposed to tight RF joints and the various intermediate solid-state junctions.

Largely unresolved at this time are the weather-dependent characteristics of the IMPs and NBs. Prior experience suggests that the August retaping of the main reflector (using latest techniques of insulation between overlapping tape junctions) will improve performance in this respect, but, as indicated by the termination of the top curve of Fig. 2, there has been no opportunity to make this evaluation.

V. Conclusions

1. Single- as well as dual-carrier noise bursts have been diminished to insignificance to the benefit of all missions. The only reservations concern the weather (as discussed above) and the presently unknown maintenance requirements (discussed or implied in many earlier reports—Refs. 3 and 17, in particular).

2. With the DSS 14 antenna and microwave equipment in "as is" condition (September 1973), the dual-carrier performance at 20 kW is more than adequate to support the Viking application, as indicated in Fig. 4. Note that the upper curve is taken from Fig. 3 and that the worst-

case Viking frequency separation offers additional margin over the nominal test conditions (Ref. 2). Reservations are as stated in (1) above.

3. It is *possible*, at least for a short period of time, to virtually eliminate both internal and external interference on a large antenna for worst-case excitation in the DSN context.

4. It is *not* considered possible to maintain the ultimate implied by (3) under normal operations for any significant period of time. It *is* considered possible, and even feasible, to achieve −160 to −170 dBm IMP means and 3-K or less NB peaks for worst-case excitation, given redesign and/or elimination of some features of the present (DSS 14) S/X-band feed cones and a dedication to the requisite operational care and maintenance.

VI. Recommendations

1. In order to maintain single-carrier improvements, recommendations of maintenance and modification have been made (Refs. 3, 15, 17, 18) applicable in some degree to any antenna, and those at DSSs 43 and 63 in particular.

2. Further, in support of single-carrier performance, a program of noise burst monitoring at DSS 14 at 400 kW as well as at other nominal operating levels is recommended, especially during the winter and spring months, to complement the summer data reported here.

3. In the event dual-carrier operation is contemplated in support of, or for enhancement of, future flight projects, recommendations for more major modifications for the 64-m network are also included in Refs. 15 and 18. These relate primarily to the external antenna and have, in the course of this program, been largely accomplished at DSS 14.

4. Finally, a firm commitment to dual-carrier operation should, in addition to the above, be supported by a thorough evaluation of and response to the S/X-band feed cone and maintenance implications of conclusion (4) above.

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Table 1. DSS 14 configuration and modification—1973

Time completed	Significant elements
Late January	PDS cone only; antenna modifications of 1970–72.
Late May	All feedcones; antenna welding (cones, tricone, subreflector), waveguide component maintenance and modifications.
Mid-July	PDS cone only (MXK and SMT removed); 100-kW klystron substituted for 400-kW.
Late July	PDS cone only; miscellaneous antenna modifications (minor welding, temporary removal/taping of service hardware).
Mid-August	PDS and MXK cones in place; extensive welding at apex and quad legs, dish detaped.
Late August	PDS and MXK cones; apex component shielding, more welding, new safety platform, dish retaped.
Mid-September	All feedcones in place, including S/X optics; full operating configuration.

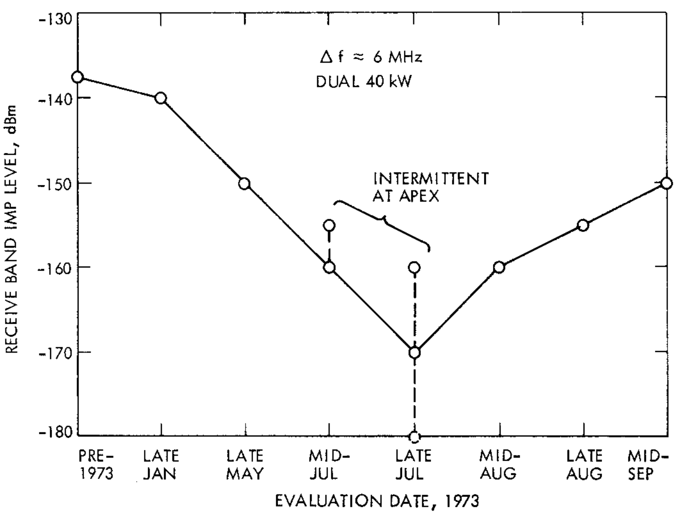

Fig. 1. DSS 14 receive band IMPs for dual 40 kW

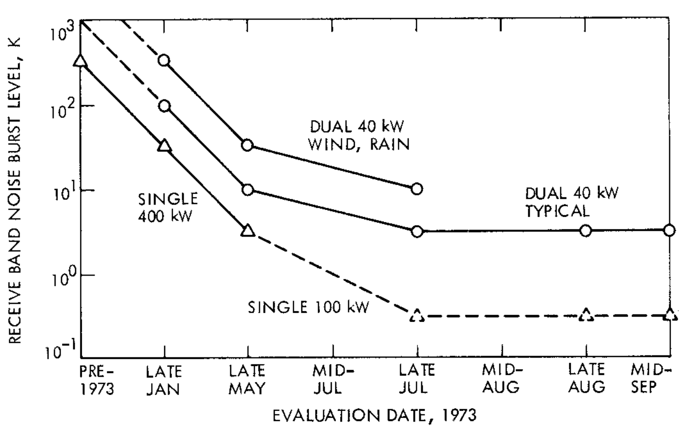

Fig. 2. DSS 14 receive band noise bursts

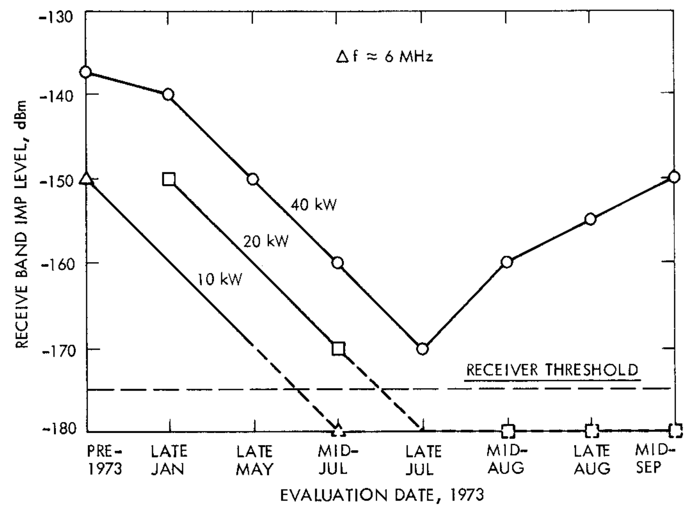

Fig. 3. DSS 14 receive band IMPs vs dual carrier power

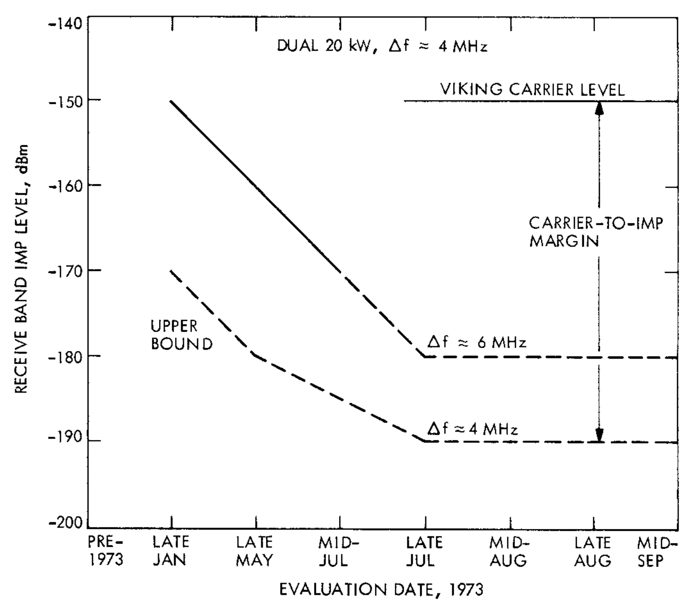

Fig. 4. DSS 14 receive band IMPs for Viking application